SECTION 350.00 - ILLUMINATION

SECTION 351.00 - INTRODUCTION

351.01 General. The primary purpose of highway illumination is to improve night visibility by providing a consistent flow of information relative to the roadway, traffic, and environmental conditions for safe and efficient driving. The geometrics such as curves, medians, intersections, and other physical features that influence driver decisions are illuminated to provide drivers more time to react to changes in the roadway. Illumination enhances traffic operations by making visible other vehicles or pedestrians so the driver can judge speed, distance, and location, particularly for heavy traffic conditions.

It is well documented that the driver continually analyzes the information available and makes speed, distance, and maneuver decisions. Poor driver decisions result from either a failure to analyze the information correctly or a failure to receive sufficient information at the right time. A failure to receive information may indicate a visibility limitation that could be corrected with lighting. A rational approach to justifying highway lighting should include evaluation of driver information needs.

- The objectives of roadway lighting are as follows:
- To supplement vehicle headlights extending the driver visibility range both laterally and longitudinally.
- To improve the visibility of roadway features and objects on or near the roadway.
- To delineate the roadway or primary roadway features.
- To provide visibility of the roadway environment.
- To reduce the apprehension of those using the roadway.

Meeting these objectives will reduce night accidents, deter crime, improve traffic operations, promote night business activities and enhance the community.

351.02 Night Visibility

351.02.01 Contrast and Surface Detail. Contrast is probably more important than visual acuity for nighttime driving performance. It is the difference between the luminance of an object and its background. If the background is well illuminated and the object is not, there is driver discernment by silhouette. Conversely, a highly illuminated object on a dark background is reverse silhouette discernment. Roadway lighting can improve the background illumination by increasing the brightness of pavement and providing a uniform brightness of objects on and adjacent to the roadway. Illumination of the surface of objects such as other vehicles, pedestrians, and curbs, improves their discernment by surface detail. Surface illumination provides color and surface detail that are needed to identify objects on or adjacent to the roadway.

351.02.02 Visual Acuity. Visual acuity is the capability of the eye to resolve small detail such as reading highway signing. Illumination improves the visual acuity by increasing the background brightness and increasing the contrast of the object. Driving requires both static and dynamic visual acuity. Static visual acuity occurs when both the driver and object being viewed are stationary. Dynamic visual acuity occurs when there is relative motion between the driver and object. The eye movements associated with motion cannot hold a steady eye image that becomes blurred with decreased contrast. Favorable dynamic visual acuity requires slow object movement, long eye-tracking time, and good illumination to enhance contrasts. The nighttime driving environment requires enhanced dynamic visual acuity to read signs, judge distance, and observe roadway objects when both the driver and object being viewed may be in motion.

351.02.03 Glare. Driver performance is affected by both discomfort and disability glare. Discomfort glare provides visual discomfort but does not reduce the ability to see an object. Disability glare is stray light at the eye also known as veiling luminance. It alters the visual field by reducing the brightness making driver discernment difficult.

Lighting should be designed and placed to reduce veiling luminance.

Frequently, private individuals and businesses install area, flood, or sign lighting fixtures that cause driver disability glare and discomfort. Some communities have ordinances that regulate and prohibit lighting that causes driver glare but the enforcement is limited. If there is private property lighting that creates driver interference, the suggested approach to revise the lighting would be as follows:

- Contact the local officials to determine if they have ordinances regulating lighting glare relative to adjacent roadways. If not, section 49-805, Idaho Code, “Display of Unauthorized Signs, Signals, or Markings” can be interpreted to address these lights since they interfere with the movement of traffic and effectiveness of other traffic control devices.

- The property owner should be contacted to discuss the impact of his lighting on adjacent traffic. It is well to provide some options to correcting the glare problem such as light repositioning or glare shields rather than total light removal.

- If the lights present a significant traffic hazard the provisions of section 49-221, Idaho Code, “Removal of Traffic Hazards” can be used to remove the lights or traffic hazard.

351.02.04 Pavement Reflectance. Because objects are seen, as noted above, based on the contrast with their background, the roadway pavement plays an important role in driver visibility. Lighting brightens the roadway surface and provides a uniform background brightness level to contrast with object illumination. Pavement brightness and surface texture must be considered in the lighting design.

351.02.05 Time. The driver requires time to see an object and identify it relative to the driving task. A moving object requires more time for the driver to target the object and determine surface detail. Illumination of the roadway permits the driver to see roadway features or objects well in advance providing additional time for the driver to make decisions.

351.03 Visibility Concept. The night driving needs require the driver to see the roadway, traffic control devices, other drivers and pedestrians, objects, and features along the roadway to allow maneuvering and stopping when required. These items must be illuminated by headlights, fixed lighting, off-roadway sources or be self-illuminated. The visibility of a roadway object depends on several factors:

- Contrast of the object's surface with the background.
- Eye adaptation relative to light and the objects.
- Magnitude of disability glare.
- Transient adaptation from eye movement between backgrounds of varying brightness.
- Background visual complexity.
- Motion dynamics.
- Object color, size, and shape.
- Driver age and visual characteristics.

351.04 Definitions. The following are general definitions of several technical terms used and the explanation of some factors considered in lighting design. An understanding of these terms and factors is essential for proper design consideration.

Average Initial Illuminance: The average level of horizontal illuminance incident on the pavement area of a traveled way at the time the lighting system is installed when lamps are new and luminaires are clean - expressed in average foot-candles (fc) for the pavement area.

Average Initial Luminance: The average level of luminance of the road surface at the time the lighting system is installed when the lamps are new and luminaires are clean - expressed in average candelas (cd)/m^2.

Average Maintained Illuminance: The average level of horizontal illuminance incident on the roadway pavement with the output of the lamp and luminaire diminished by the light loss factors expressed in average candelas/m^2.

Candela: The unit of luminous intensity. Formerly the term “candle” was used (cd).

Candela Per Square Foot: The unit of luminance (photometric brightness) equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen (1m)/m^2, or the average luminance of any surface emitting or reflecting light at that rate. One cd/sq ft, equals 10.76 cd/m^2.

Candela Per Square Meter: The International System (the French abbreviation SI is used) unit of luminance (photometric brightness) equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of lm/m^2 or the average luminance of any surface emitting or reflecting light at that rate. One cd/m^2 equals 0.0929 cd/sq ft.

Candlepower: Luminous intensity in a specified direction — expressed in candelas.

Complete Interchange Lighting: The lighting of the freeway through-traffic lanes through the interchange, the traffic lanes of all ramps, the acceleration and deceleration lanes, all ramp terminals, and the crossroad between the outermost ramp terminals.

Equipment Factor: A factor used in the illuminance or luminance calculations that compensates for light losses due to normal production tolerances of commercially available luminaires when compared with laboratory photometric test models. It is common practice to approximate these losses using a 5 percent to 10 percent loss factor.

Foot-candle: The illuminance on a surface 1 sq ft (0.09 m^2) in area on which there is uniformly distributed a light flux of 1 lm. One foot-candle (fc) equals 10.76 lux.

Light Loss Factor: The depreciation factors that are applied to the calculated initial average luminance or illuminance to determine the value of average maintained (depreciated) luminance or illuminance at a predetermined time in the operating cycle, usually just prior to relamping, and which reflect the decrease in effective light output of a lamp and luminaire during its life. It is made up of several variables, and judgment must be exercised to arrive at a suitable factor. The more important variables that should be considered when determining the light loss factors are:

- Decrease of lamp lumen output with burning hours (LLD, Lamp Lumen Depreciation);
- Reduction of some discharge lamp light output when operated in other than the vertical position;
- Schedule of lamp replacement;
- Frequency and effectiveness of luminaire cleaning (LDD, Luminaire Dirt Depreciation);
- Equipment Factor (EF); and
- Operation of light sources at other than rated current or voltage.

Lumen: A unit of measure of the quantity of light. One lumen is the amount of light that falls on an area of 1 sq ft (0.09 m^2), every point of that is 1 foot (0.3 m) from the source of 1 cd. A light source of 1 cd emits a total of 12.57 lm.

Luminaire: A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Luminaire Cycle: The distance between two luminaires along one side of the roadway. NOTE: This may not be the same as luminaire spacing along the centerline - considering both sides of the road.

Luminance: The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

Luminous Efficacy of a Source of Light: The quotient of the luminous flux emitted by the total lamp power input. It is expressed in lumens per watt (lm/W).

Lux: The International System (SI) unit of illuminance. It is defined as the amount of light on a surface of 1 m^2, all points of which are 1 m from a uniform source of 1 cd. One lux (lx) equals 0.0929 foot-candle.

Partial Interchange Lighting: The lighting that consists of a few luminaires located in the vicinity of some or all ramp terminals. The usual practice is to light those general areas where the exit and entrance ramps connect with the through traffic lanes of the freeway and generally light those areas where the ramps intersect the crossroad.

Uniformity of Illuminance: The ratio of average foot-candies of illuminance on the pavement area to the foot-candles at the point of minimum illuminance on the pavement. It is commonly called the *uniformity ratio.* A uniformity ratio of 3:1 means the average foot-candle value on the pavement is three times the foot-candle value at the point of least illuminance on the pavement. A further consideration is to maintain a ratio of 10:1 between the points of maximum illuminance and minimum illuminance.

Uniformity of Luminance: The average level-to-minimum point method uses the average luminance of the roadway design area between two adjacent luminaires, divided by the lowest value at any point in the area. The maximum-to-minimum point method uses the maximum and minimum values between adjacent luminaires. The luminance uniformity (avg/min and max/min) considers the traveled portion of the roadway, except for divided highways having different designs on each side.

Veiling Luminance: A luminance superimposed on the retinal image that reduces its contrast. It is this veiling effect produced by bright sources or areas in the visual field that results in decreased visual performance and visibility.

SECTION 352.00 - INSTALLATION AND MAINTENANCE RESPONSIBILITY

352.01 General. ITD is responsible for lighting the state highway system outside the city limits of communities. On urban extensions of the state highway system, this responsibility is shared with the communities. ITD is not responsible for lighting off the state highway system.

352.02 Installation Responsibility. Installation responsibility of highway illumination will depend on needs and requirements. Cost participation will depend on the location. Designation of this responsibility will generally be:

352.02.01 Within Corporate Limits of a Community

Interstate Projects: ITD, using approved federal aid, will participate in the cost of approved lighting installations.

STP Local Projects: ITD, using approved federal aid, will participate in installation costs of approved lighting provided the city will assume all maintenance and operation costs.

State Projects: ITD will assume the entire cost of approved lighting projects provided the city will assume all operation and maintenance costs.

Community Projects: Highway lighting may be installed on the state highway system by the community as a separate installation or as an addition to items listed above. These installations must be approved by ITD with the community responsible for all installation, maintenance and operation costs.

352.02.02 Outside Corporate Limits of a Community. The cost of all street lighting will usually be the responsibility of the state. However, a community may light an intersection or interchange leading to the community. These installations must be approved by the state with the local agency responsible for all installation, maintenance, and operation costs.

352.03 Project Approval. Highway illumination can be constructed as a portion of a federal aid project or as a state improvement project. Each installation, modernization, alteration, or improvement must be approved by the Traffic Engineer.

Project programming requests should include the lighting requirements together with justification and cost data. Justification for highway illumination should be in accordance with the warranting conditions outlined herein.

Lighting installations and improvements not covered in the approved project should be submitted separately to the Headquarters Traffic Section for approval. The following information is required:

- Description of work.
- Justification.
- Recommended method of accomplishing work (federal-state contract, state forces, state contract, or city forces).
- City concurrence of improvement if installation is within corporate limits of community.
- Cost estimate.

Lighting plans and specifications shall be prepared in the district office. The Headquarters Traffic Section will review the plans in accordance with normal project reviews and approval. Illumination plans shall be signed by the engineer in responsible charge of the design.

352.04 Maintenance Responsibility. Highway illumination on the state highway system outside the corporate limits of a community shall be the responsibility of ITD relative to ownership, operation costs, maintenance and replacement requirements. However, cities may, by agreement, assume these responsibilities on installations near their community.

Maintenance and electrical energy responsibilities for lighting on the state highway system within the corporate limits of a community shall be covered by an agreement. The community shall normally accept ownership of the entire lighting system and all costs of operation and maintenance.

Overhead guide sign illumination shall generally be ITD responsibility including those overhead sign installations on interchange crossroads that provide highway directional information.

Lighting installed on the ramps or through-lanes of the interstate shall be operated and maintained by ITD. Crossroad lighting shall be operated and maintained by the local agency when inside the city limits. Maintenance of crossroad lighting outside the city limits is the responsibility of ITD, except for agreed to operate and maintain.

Lighting installed in conjunction with intersection traffic signals relative to installations, maintenance, and operation costs shall be the same responsibility - ITD or city - as assigned by agreement for the traffic signal installation.

352.05 Maintenance Requirements. Adequate maintenance requires systematic cleaning and regular inspection. Dirt on lamp reflectors and enclosing glassware is the largest contributor to lighting depreciation.

Lamp glassware and reflectors should be cleaned annually. Semiannually may be necessary in very dirty locations.

A regular maintenance schedule of lamp replacement and luminaire cleaning should be established to maintain the efficiency of the lighting system.

352.06 Agreements. Agreements are necessary between ITD and communities or utility companies for highway illumination to define work to be performed by each party, cost participation, maintenance responsibilities, and other special requirements. General agreement types follow.

352.06.01 Federal Aid Agreements with Communities. Agreement clauses for highway and sign lighting installations will be included as part of the cooperative project agreement with the community. The Headquarters Traffic Section shall coordinate the agreement requirements with the district.

352.06.02 Cooperative Highway Lighting Agreement. An agreement between ITD and communities outlining conditions relative to constructions ownership, maintenance, replacement, and operation of street lighting is required for all installations having state participation that are not a part of a current project. This agreement will be prepared by the district and transmitted to the Headquarters Traffic Section for review prior to ITD approval. In all cases, an agreement shall be approved before work is started.

352.06.03 Electric Service Agreements. The districts will prepare energy supply agreements or agreement addendums with utility companies for lighting installations maintained and operated by ITD except for installations within Idaho Power jurisdiction. The Headquarters Traffic Section will prepare the Idaho Power agreement addendums. The districts must provide information regarding the number and type of luminaires and the date that the system is energized. The cities are responsible for agreements on lighting installations that they maintain and operate.

Utility company service request forms (service orders) can be prepared by the district for all electric utility companies except as indicated above in accordance with the utility company requirements. A service order is adequate since the utility rate schedules defining costs and maintenance responsibilities are accepted and approved by the state Public Utilities Commission.

352.06.04 Railroad Agreements. An agreement is required with the railroad company when any portion of the lighting system is located within the railroad right-of-way. The Headquarters Traffic Section shall coordinate these requirements with the Utilities Engineer for preparation and completion of the railroad agreements.

352.07 Electric Service. The source and availability of electrical energy must be discussed and coordinated with the utility company during lighting design. Information will have to be furnished to the utility company on voltage, electrical load, desirable service point, and special electrical equipment requirements.

It is recommended that the illumination contractor or subcontractor be responsible for scheduling electrical service for all illumination installations and pay all costs associated with the electrical service. This provides the contractor the opportunity to deal directly with the utility company and obtain electrical service when it is needed to meet the work schedule. The contractor needs to be advised that there is usually a payment for a new electrical service drop and that payment must be included in his lump sum bid for the illumination. The requirement can be implemented by including the following special provision in the contract:

"It will be the contractor's responsibility to contact the appropriate power company to make the initial power hookup in a timely manner. Fees charged by the power company, if any, shall be paid by the contractor and will be reimbursed to the contractor at power company invoice cost."

352.08 Construction Inspection. Highway lighting must be in conformance with the various electrical codes, safety codes, and regulations. The District Traffic Engineer should assist the Resident Engineer on any problems or questions that develop. A representative of the Headquarters Traffic Section will be available on request for field assistance and consultation on special problems.

Electrical subcontractors should attend the preconstruction conference on all projects with illumination work. If this is not possible, then a separate meeting with the electrical subcontractor is recommended to answer all questions prior to construction. It is suggested that the following items be discussed:

- Review project plans and specifications.
- Discuss material approval procedures, state-furnished material, approval of pole shop drawings, and delivery delays.
- Clarify any special construction or material requirements.
- Compliance with State Electrical Board permit requirements prior to starting work.

It is important that the lighting equipment and material be properly installed to prevent future maintenance costs. Construction inspection personnel should be able to handle most of the inspecting work after some experience and indoctrination on installation requirements. Items that have created problems in the past are pole locations, foundation elevations, breakaway hardware, conduit installations, anchor bolt placement, location of expansion fittings, pulling electrical circuits, and installing service pole equipment.

352.09 Maintenance Records And Inspection. Routine inspection of lighting installations is necessary to insure efficient operation and adequate maintenance. Prompt attention to luminaire knockdowns, lamp outages, and malfunctions is important to avoid vehicle operational problems and for good public relations.

The District Traffic Engineer should make semiannual inspections of all lighting equipment. Support poles, luminaires, mast arms, etc., should be observed for damage or unapproved alterations.

District maintenance personnel should make periodic visual checks of all fight units for glass breakage, equipment damages and apparent malfunctions. The District Traffic Engineer should be promptly notified of discrepancies in existing light units and construction of new lighting on highway right-of-way.

SECTION 353.00 - CLASSIFICATION OF ILLUMINATION

353.01 General. The classification of illumination systems falls into several categories dependent on type of light distribution, light source, and electrical distribution system. The light distribution types follow definite patterns established by the Illuminating Engineering Society (ies) and are selected according to the roadway area to be illuminated. Electrical distribution systems can be overhead or underground using either multiple or series electrical circuits. The basic requirements, advantages, and disadvantages are each presented so that the applicable type can be selected for any particular location. A full discussion of illumination systems' specific features and design considerations are presented in the Roadway Lighting Handbook, U.S. Department of Transportation, Federal Highway Administration, Implementation Package 78-15, December 1978. This publication is supplemented by an addendum to Chapter Six, "Designing the Lighting System Using Pavement Luminance," U.S. DOT, FHWA, September 1983. Copies of both publications are available from the U.S. Government Printing Office, Washington DC 20402.

353.02 Light Sources. The first consideration in lighting design is the selection of light source. Each type of lighting has specific characteristics and features that influence the lighting system design depending on light source selected. The features of efficient lamp types are as follows:

353.02.01 Incandescent Lamps. Incandescent is the oldest and best known light source. However, it has low light-producing efficiency for power usage so it is not normally used for outdoor lighting.

353.02.02 Fluorescent Lamps. Fluorescent lamps have been used for sign lighting and underpass lighting applications. They require a ballast for high starting voltages. The luminaires are large units with difficult light distribution characteristics. There are some fluorescent lighting applications in tunnels with low mounting heights since fluorescent lamps produce relatively low-glare problems.

Fluorescent sign lighting fixtures are no longer used because of fixture costs and high maintenance requirements.

353.02.03 Mercury-Vapor. Mercury-vapor has had widespread use in roadway lighting because of the high lumen output per watt and relatively long-rated lamp life. In the past, there was some concern over color rendition but those concerns have substantially disappeared. A phosphor-coated lamp is available for applications where color rendition is an important consideration. Mercury-vapor lighting is being replaced by other light sources because of its relatively low efficiency.

353.02.04 Metal Halide Lamp. Metal halide lamps produce better color of higher efficiency than mercury-vapor lamps but have a shorter lamp life. They are also sensitive to lamp orientation and vibration damage. They are generally used for high-mast lighting and sports arenas where large area-type lighting is needed.

353.02.05 High-Pressure Sodium. The most recent and probably widest used lamp for roadway lighting is the high-pressure sodium lamp. It provides excellent efficiency, good lumen maintenance, long life and fair color rendition. It is a discharge lamp requiring a ballast that should be located in conjunction with the fixture.

353.02.06 Low-Pressure Sodium. The low-pressure sodium is the most efficient lamp source available today. However, it is a large unit and has monochromatic color disadvantages. It has been used in roadway lighting where color and optical control are of less importance and in tunnels where high illumination levels are required.

ITD has standardized on high-pressure sodium lamps for roadway lighting and sign lighting applications.

353.03 Ballasts. All gas discharge lamps require a ballast and starting device to start and operate the lamps. The ballast provides the voltage to start the lamp, keeps the lamp operating within its design parameters, and adapts the lamp to the line voltage. Most ballasts in use are integral to the luminaire housing providing good accessibility and economic costs.

353.04 Luminaire Supports. The luminaire support consists of the pole, pole base, and mast arm to hold the luminaire in place. Mast arms are available in various lengths but should be adequate to place the luminaire over the edge of roadway. Poles are available in a variety of materials with ITD normally specifying galvanized steel poles. The pole length shall provide a mounting height of 40 feet (12.19 m) in urban areas and 50 feet (15.24 m) for interstate lighting, unless prohibited by overhead obstructions.

Some communities desire and use specific pole designs that are selected architecturally to fit street hardware standards. These specialty poles can be used on the state highway system to meet the community aesthetic standards. All poles shall be galvanized with any architectural enhancements provided by special coatings over the galvanizing. The community shall be responsible for any additional lighting costs associated with a decorative design.

The luminaire supports shall include a breakaway base design as needed to comply with AASHTO roadside design criteria in areas with a design speed greater than 35 miles per hour. Normally, a breakaway pole base is not required on urban curb and gutter sections with a design speed of 35 miles per hour or less. Support poles located behind barrier rail, bridge rail, or other areas not accessible by vehicles, do not require breakaway design. ITD uses a steel frangible coupler for 50-foot (15.24 m) and shorter poles with a breakaway connector for the electrical circuit.

353.05 Electrical Distribution System. On ITD installations, the electrical distribution system should be a multiple underground system. Maximum branch circuit potential should be limited to 240 volts. Overhead wiring can be used for temporary lighting in conjunction with wood poles because of the ease of installation, convenient removal, and economical cost.

SECTION 354.00 - ILLUMINATION REQUIREMENTS

354.01 General. The installation of lighting on the interstate and state highway systems shall comply with the current AASHTO Information Guide for Roadway Lighting. This publication addresses levels of illumination and conditions that require street lighting. These guidelines shall apply except as noted below.

354.02 Signalized Intersections. Street illumination shall be installed in conjunction with each traffic signal installation at intersections. However, lighting is not required on temporary signal installations, emergency vehicle signals, and daylight only pedestrian signals. The luminaires should be designed for installation on combination signal-lighting poles to reduce the intersection roadside hardware. The installation, maintenance and operational responsibility for the intersection illumination shall be the same as the traffic signal installation.

354.03 Overhead Sign Installations. All overhead signs installed on the state highway system should have external illumination if electrical service is readily available. ITD installs only those overhead signs that are considered primary for good driver guidance and accordingly illumination is a portion of this primary decision. Observation of sign installations indicates that the legibility of non-illuminated overhead signs is less than desirable.

354.04 Bypass Highway Routes On occasion, highway routes are relocated to bypass communities and/or business activities. In cooperation with the community, the illumination of the major intersection or intersections leading to the community and available services should be considered.

354.05 Partial Interchange Lighting. Partial interchange lighting shall be based on each half of the interchange. Where each half or combination of “on-off” ramps for one direction exceed 3500 ADT, then partial interchange lighting should be considered. The general configuration of partial illumination is shown in Figure 354.05-01.

At interchanges that do not warrant illumination but may have justification in the foreseeable future (i.e., 10 years), underground conduit for future illumination should be installed under the roadways. Figure 354.05-02 illustrates typical conduit installation locations for future interchange illumination.

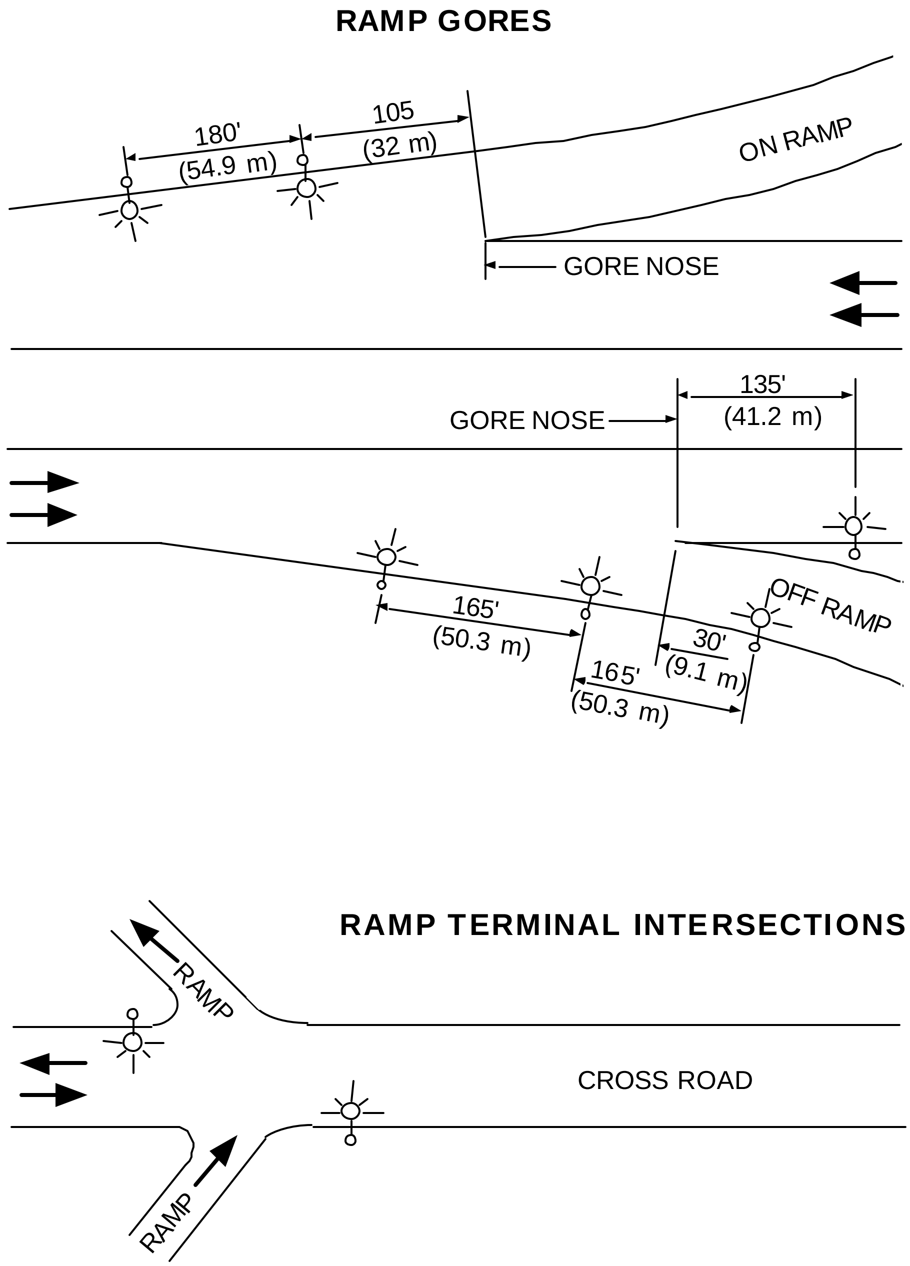

Figure 354.05-01 Partial Interchange Illumination

RAMP GORES

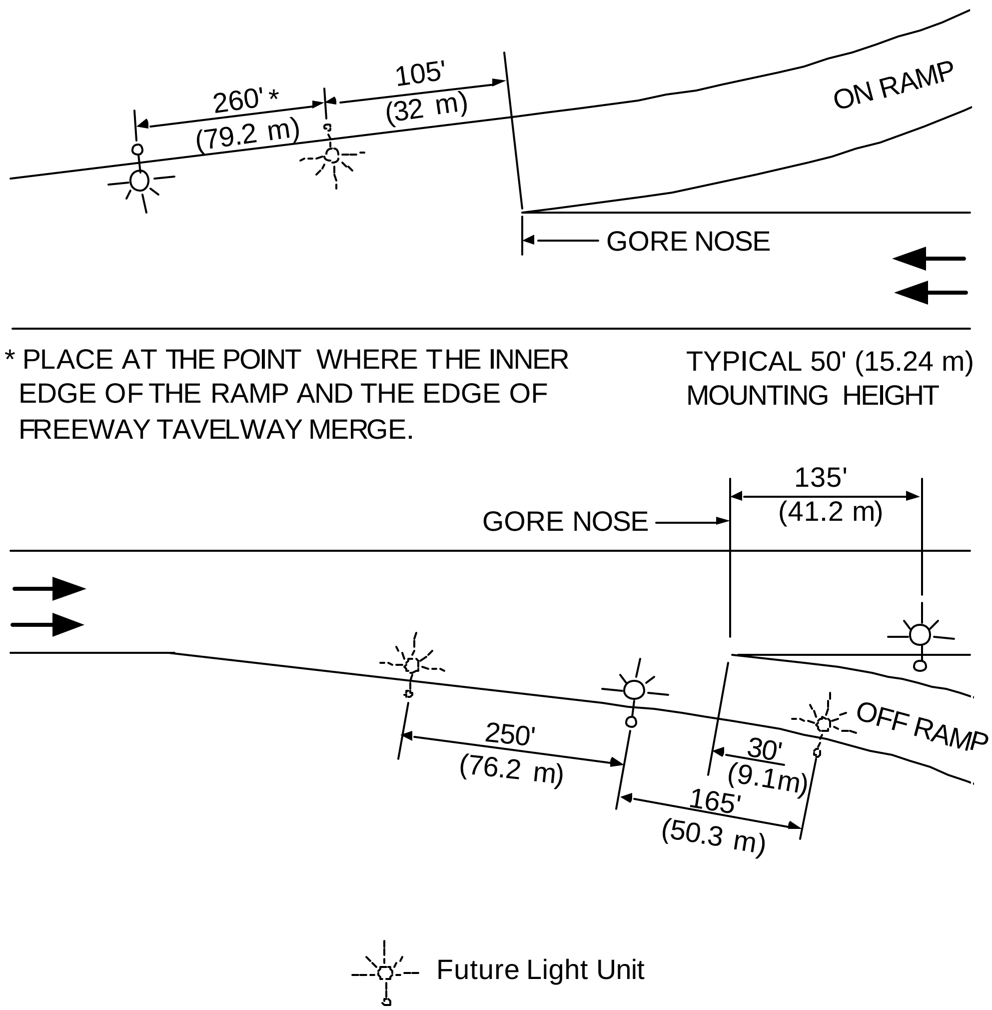

Figure 354.05-02 Partial Interchange Illumination Minimum Lighting

354.06 Weigh Stations And Rest Areas. Illumination is generally required in weigh stations and rest areas to delineate the layout of the facility and parking areas and enhance user safety. Lighting should be included in all projects to upgrade existing facilities and new facilities. Because of the design variations in these types of installations, the lighting design must be tailored to each site based on the layout, operational considerations, and recommended illumination levels.

354.07 Analysis Of Lighting Needs. The justification of lighting needs is required to support the funding approval of illumination projects. In some cases, as noted above, lighting requirements are specifically defined based on traffic volumes or type of roadway facility. In other cases, such as urban roadways, the need for lighting is based on detailed analysis and engineering judgments. Figures 354.07-01 and 354.07-02 are two evaluation forms that may be used for non-controlled access roadways and intersections to determine lighting requirements. The use of these forms is explained in the FHWA Roadway Lighting Handbook if additional information is needed. Districts should complete and submit these forms as their analysis of lighting requirements and support of any lighting recommendations.

354.08 Long Underpasses And Tunnels. The state highway system has no tunnels and relatively few long underpasses that require special lighting consideration and design. Each facility of this nature will be handled as a special project with the design developed by the Headquarters Traffic Section.

EVALUATION FORM FOR NON-CONTROLLED ACCESS FACILITY LIGHTING

CLASSIFICATION FACTOR	RATING 1	RATING 2	RATING 3	RATING 4	RATING 5	UNLIT WEIGHT (A)	LIGHTED WEIGHT (B)	DIFFERENCE (A – B)	SCORE [RATING x (A – B)]
Geometric Factors									
No. of lanes	4 or less	—	6	—	8 or more	1.0	0.8	0.2	
Lane Width	> 12' (3.6 m)	12' (3.6 m)	11' (3.3 m)	10' (3.0 m)	< 10' (3.0 m)	3.0	2.5	0.5	
Median Openings per Mile	< 4.0 or one-way operation	4.0 – 8.0	8.1 – 12.0	12.0 – 15.0	> 15.0 or no access control	5.0	3.0	2.0	
Curb Cuts	< 10%	10 – 20%	20 – 30%	30 – 40%	> 40%	5.0	3.0	2.0	
Curves	< 3.0°	3.1 – 6.0°	6.1 – 8.0°	8.1 – 10.0°	> 10°	13.0	5.0	8.0	
Grades	< 3%	3.0 – 3.9%	4.0 – 4.9%	5.0 – 6.9%	7% or more	3.2	2.8	0.4	
Sight Distance	> 700' (213.4 m)	500 – 700' (152.4 – 213.4 m)	300 – 500' (91.4 – 152.4 m)	200 – 300' (61 – 91.4 m)	< 200' (61 m)	2.0	1.8	0.2	
Parking	prohibited both sides	loading zones only	off-peak only	permitted one side	permitted both sides	0.2	0.1	0.1	
								Geometric Total	
Operational Factors									
Signals	all major intersections signalized	substantial majority of intersections signalized	most major intersections signalized	about half the intersections signalized	frequent non-signalized intersections	3.0	2.8	0.2	
Left Turn Lane	all major intersections or one-way operation	substantial majority of intersections	most major intersections	about half the major intersections	infrequent turn bays or undivided streets	5.0	4.0	1.0	
Median Width	30' (9.1 m)	20 – 30' (6.1 – 9.1 m)	10 – 20' (3.1 – 6.1 m)	4 – 10' (1.2 – 3.1 m)	0 – 4' (0 – 1.2 m)	1.0	0.5	0.5	
Operating speed	25 or less	30	35	40	45 or greater	1.0	0.2	0.8	
Pedestrian Traffic at Night (peds/mi)	very few or none	0 – 50	50 – 100	100 – 200	≥ 200	1.5	0.5	1.0	
								Operational Total	
Environmental Factors									
% Development	0	0 – 30%	30 – 60%	60 – 90%	100%	0.5	0.3	0.2	
Predominant Type Development	undeveloped or back-up design	residential	half residential &/or commercial	industrial or commercial	strip industrial or commercial	0.5	0.3	0.2	
Setback Distance	> 200' (61 m)	150 – 200' (45.7 – 61 m)	100 – 150' (30.5 – 45.7 m)	50 – 100' (15.2 – 30.5 m)	> 50' (15.2 m)	0.5	0.3	0.2	
Advertising or Area Lighting	none	0 – 40%	40 – 60%	60 – 80%	essentially continuous	3.0	1.0	2.0	
Raised Curb Median	none	continuous	at all intersections	at signalized intersections	a few locations	1.0	0.5	0.5	
Crime Rate	extremely low	lower than city average	city average	higher than city average	extremely high	1.0	0.5	0.5	
								Environmental Total	
Accidents									
Ratio of Night-to-Day	< 1.0	1.0 – 1.2	1.2 – 1.5	1.5 – 2.0	2.0*	10.0	2.0	8.0	
								Accident Total	
								Sum Total	
								Warranting Condition	85 points

*Continuous lighting warranted

Figure 354.07-01 Evaluation Form For Non-Controlled Access Facility Lighting

EVALUATION FORM FOR INTERSECTION LIGHTING

CLASSIFICATION FACTOR	RATING 1	RATING 2	RATING 3	RATING 4	RATING 5	UNLIT WEIGHT (A)	LIGHTED WEIGHT (B)	DIFFERENCE (A – B)	SCORE [RATING x (A – B)]
Geometric Factors									
No. of legs		3	4	5	6 or more (including traffic circles)	3.0	0.8	0.5	______
Approach Lane Width	> 12' (3.6 m)	12' (3.6 m)	11' (3.3 m)	10' (3.0 m)	< 10' (3.0 m)	3.0	2.5	0.5	______
Channelization	no turn lanes < 10%	left turn lanes on major legs	left turn lanes on all legs, right turn lanes on major legs	left and right turn lanes on major legs	left and right turn lanes on all legs	2.0	1.0	1.0	______
Approach Sight Distance	< 700' (213.4 m)	500 – 700' (152.4 – 213.4 m)	300 – 500' (91.4 – 152.4 m)	200 – 300' (61 – 91.4 m)	> 200' (61 m)	2.0	1.8	0.2	______
Grades on Approach Streets	< 3%	3.0 – 3.9%	4.0 – 4.9%	5.0 – 6.9%	7% or more	3.2	2.8	0.4	______
Curvature on Approach Legs	> 3.0°	3.0 – 6.0°	6.1 – 8.0°	8.1 – 10.0°	> 10°	13.0	5.0	8.0	______
Parking in Vicinity	prohibited both sides	loading zones only	off-peak only	permitted one side	permitted both sides	0.2	0.1	0.1	______
							Geometric Total		
Operational Factors									
Operating Speed on Approach Legs	25 mph or less	30 mph	35 mph	40 mph	45 mph or greater	1.0	0.2	0.8	______
Type of Control	all phases signalized (incl. turn lanes)	left turn lane signal control	through traffic signal control only	4-way stop control	stop control to minor legs or no control	3.0	2.7	0.3	______
Channelization	left and right signal control	left and right turn lane signal control on major legs	left turn lane signal control on all legs	left turn lane signal control on major legs	no turn lane control	3.0	2.0	1.0	______
Level of Service (Load Factor)	A 0.0	B 0 – 0.1	C 0.1 – 0.3	D 0.3 – 0.7	E 0.7 – 1.0	1.0	0.2	0.8	______
Pedestrian Volume (peds/hr crossing)	very few or none	0 – 50	50 – 100	100 – 200	≥ 200	1.5	0.5	1.0	______
							Operational Total		
Environmental Factors									
% Adjacent Development	0	0 – 30%	30 – 60%	60 – 90%	100%	0.5	0.5	0.2	______
Predominant Development near Intersection	undeveloped	residential	50% residential 50% industrial or commercial	industrial or commercial	strip industrial or commercial (no circuitry)	0.5	0.5	0.2	______
Lighting in Immediate Vicinity	none	0 – 40%	40 – 60%	60 – 80%	essentially continuous	3.0	1.5	1.5	______
Crime Rate	extremely low	lower than city average	city average	higher than city average	extremely high	1.0	0.5	0.5	______
							Environmental Total		
Accidents									
Ratio of Night-to-Day Accident Rates	< 1.0	1.0 – 1.2	1.2 – 1.5	1.5 – 2.0	2.0*	10.0	2.0	8.0	______
							Accident Total		
							Sum Total		
*Continuous lighting warranted							***Warranting Condition***		85 points

Figure 354.07-02 Evaluation Form For Intersection Lighting

SECTION 355.00 - DESIGN REQUIREMENTS

355.01 Lighting System Design. The design of a lighting system involves a balance of lumens, pole spacing and luminaire characteristics to provide the desired illumination intensity and uniformity of lighting between units. A lighting system can be readily designed using available computer software that performs the necessary calculations to determine the system characteristics. ITD presently uses the General Electric “Aladdin” computer program based on GE lighting fixtures. This program is available for application to any lighting design requirements.

Special attention must be directed to luminaire spacing in the lighting design if cutoff optics fixtures are used. These fixtures are available in full and semi-cutoff lighting distributions that will affect the luminaire spacing and lighting uniformity ratios.

355.02 Lighting Circuit Calculations. The major points to consider when designing a multiple light circuit are current capacity of the wire and voltage drop. The light output of all lamps varies directly with the voltage. Additionally, some lamps will not start and operate satisfactorily if the voltage is below specified levels.

Voltage drop is caused by the resistance of the conductor to current flow. Unless provisions for this are made in calculating conductor sizes, there may be a substantial difference between the voltage at the service point and point of use. Voltage drop can be minimized by either: (1) using a higher system voltage (240/480 volts rather than 120 volts); (2) using larger wire; (3) reducing the number of luminaires on the circuit; (4) relocating the supply point; or (5) any combination of the above.

355.02.01 Definitions and Special Terms

Ampere: The practical unit of rate of flow of electricity, analogous to “gallons per minute” in hydraulics.

Volt: The unit of electromotive-force. It is the unit whereby the tendency to establish electric current may be measured.

Resistance: The name that has been given to the opposition to the flow of an electric current.

Voltage Drop: Caused by the resistance of the conductor to current flow.

The basic formula for determining the size of conductor for a given length, voltage drop, and current is:

$$\text{Circular Mils} = \frac{2K \times L \times I}{\text{Voltage Drop}}$$

Where:

K = Resistance of conductor material in ohms per circular mil foot. Use 12-ohms for a circuit loading of 50 to 100 percent of allowable conductor current-carrying capacity for copper wire.

L = Cumulative length of circuit from power source.

I = Current load of circuit in amperes.

Circular Mils = Area of a conductor in circular mils.

Allowable Voltage Drop = 3 percent of applied *nominal voltage* on circuit. A 3 percent factor is used to provide ample voltage for operation of high pressure sodium ballasts.

355.02.02 Basic Design Criteria

Nominal Voltage	Load Per Lamp	
480 v	400 Watt	1.00 amp
240 v	400 Watt	2.00 amp
120 v	400 Watt	4.00 amp
480 v	250 Watt	0.70 amp
240 v	250 Watt	1.40 amp
120 v	250 Watt	2.70 amp

These are only used as examples for the calculations that follow. Specific manufacturers' data should be used based on fixture and ballast design.

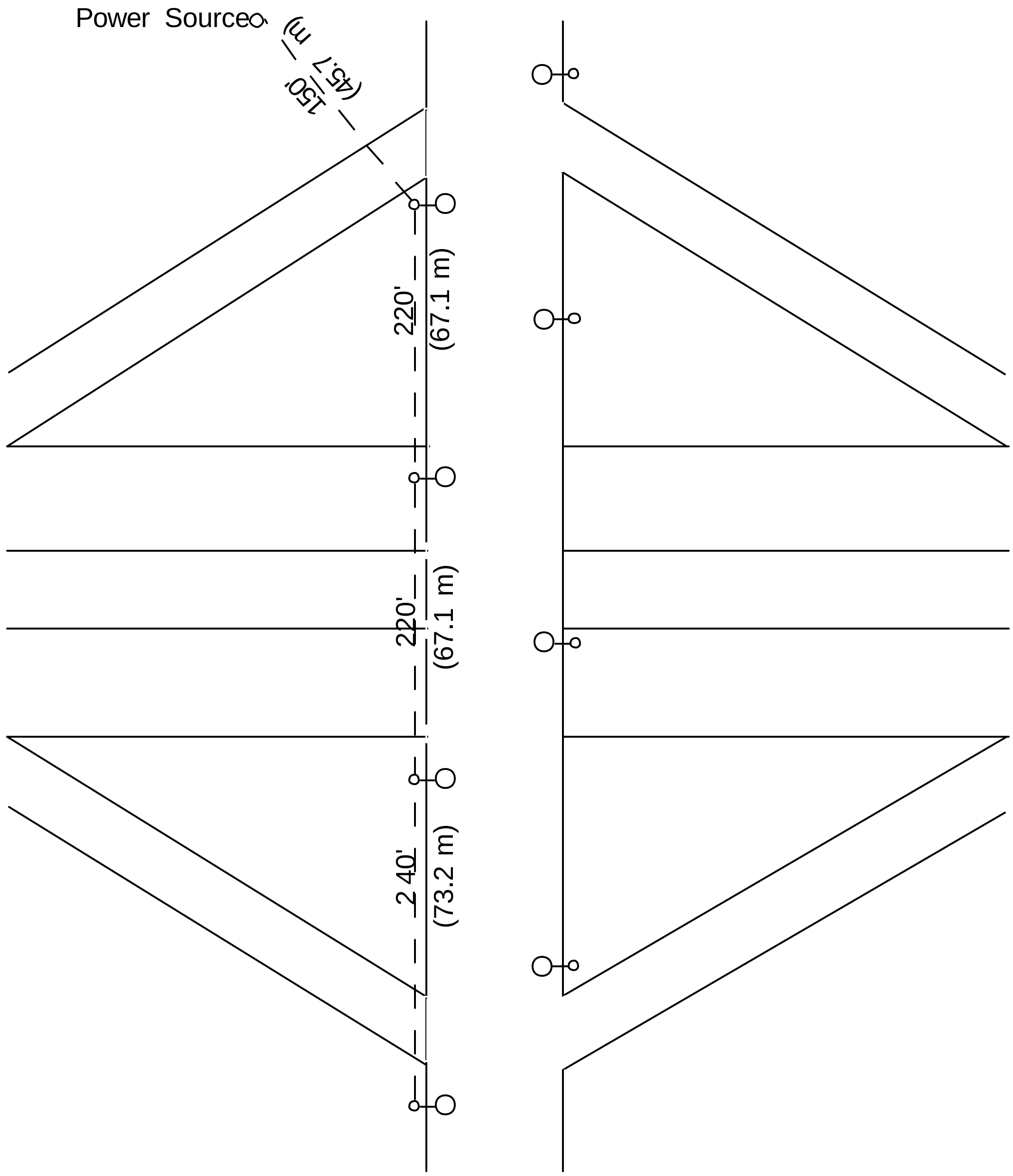

Figure 355.02-01   Multiple Lighting System Continuous Conduit

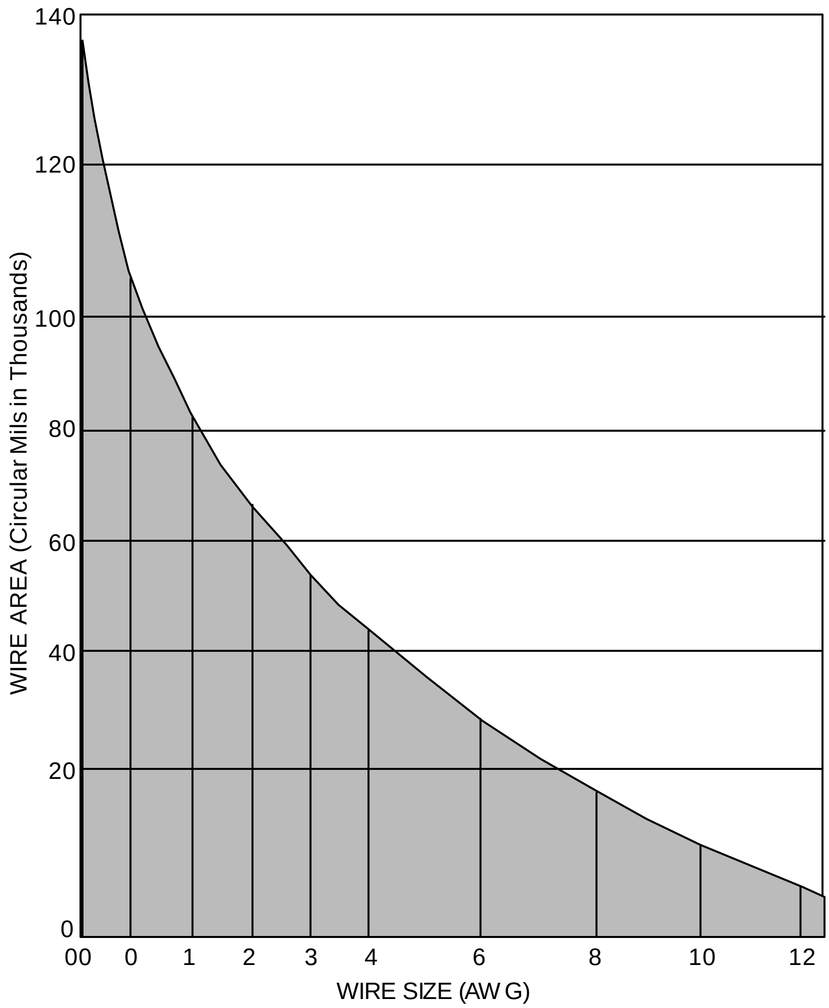

Figure 355.02-02 Wire Area vs. Wire Size

Problem: Determine wire size for the following lighting circuit (see Figure 355.02-01)

Circuit voltage - 240 volts

Lamps - 400 watt high pressure sodium

Distances between light poles – 150' (45.7 m), 220' (67.1 m), and 240' (73.2 m)

Section	Cumulative Length	Length & Amperes				
1	150' (45.7 m)	150	x	2.1	=	315
2	150' (45.7 m)	370	x	2.1	=	777
	220' (67.1 m)					
3	150' (45.7 m)	590	x	2.1	=	1239
	220' (67.1 m)					
	220' (67.1 m)					
4	150' (45.7 m)	830	x	2.1	=	1743
	220' (67.1 m)					
	220' (67.1 m)					
	240' (73.2 m)					
		L	x	I	=	4074

Allowable Voltage Drop = (0.03)(240) = 7.2 volts

355.02.03 Inserted Into Formula:

$$\frac{2 \times 12 \times 4{,}074}{7.2} = 13{,}580 \text{ Circular Mils} = \#8 \text{ AWG Wire}$$

(See Figure 355.02-02 for wire areas vs. wire size)

The above computations are for a continuous circuit; however, highway lighting circuits must split at times to service light units across streets or in gore locations. The method of determining size of wire is basically the same except that each branch of the circuit must be figured as a separate circuit from the power source. After determining wire to each branch, the same procedure is used to figure size of wire from the junction of the two branches back to the power source. It must be remembered at this time that the wire size must be large enough on the branches to provide the limits of voltage drop. Also, the wire from the split to the power source must be sufficient to accommodate both branch voltage drops.

Problem: Determine wire size for the following light circuit (see Figure 355.02-03)

Circuit voltage: 240 volts

Lamps: 400 watt high pressure sodium

150 watt high pressure sodium

Distance between light poles:

- lst Branch 160' (48.8 m) and 80' (24.4 m)
- 2nd Branch 165' (50.3 m) and 165' (50.3 m)
- Main Circuit 100' (30.5 m) and 840' (256 m)

Allowable Voltage Drop = (0.03) (240) = 7.2 volts

lst Branch:

Section	Accumulative Length	Length & Amperes
1	100' (30.5 m) 840' (256 m) 160' (48.8 m)	1100 x 2.1 = 2310
2	100' (30.5 m) 840' (256 m) 160' (48.8 m) 80' (24.4 m)	1180 x 4.1 = 4838
		L x I = 7148

$\frac{2 \times 12 \times 7148}{7.2} =$ 23,826 circular Mils = #6 AWG wire (minimum size used)

2nd Branch:

Section	Accumulative Length	Length & Amperes				
1	100' (30.5 m)	100	x	2.1	=	210
2	100' (30.5 m)	940	x	2.1	=	1974
	840' (256 m)					
3	100' (30.5 m)	1105	x	2.1	=	2320
	840' (256 m)					
	165' (50.3 m)					
4	100' (30.5 m)	1270	x	2.1	=	2667
	840' (256 m)					
	165' (50.3 m)					
	165' (50.3 m)					
		L	x	I	=	7171

$\frac{2 \times 12 \times 7171}{7.2} =$ 23,903 Circular Mils = #6 AWG (minimum size used)

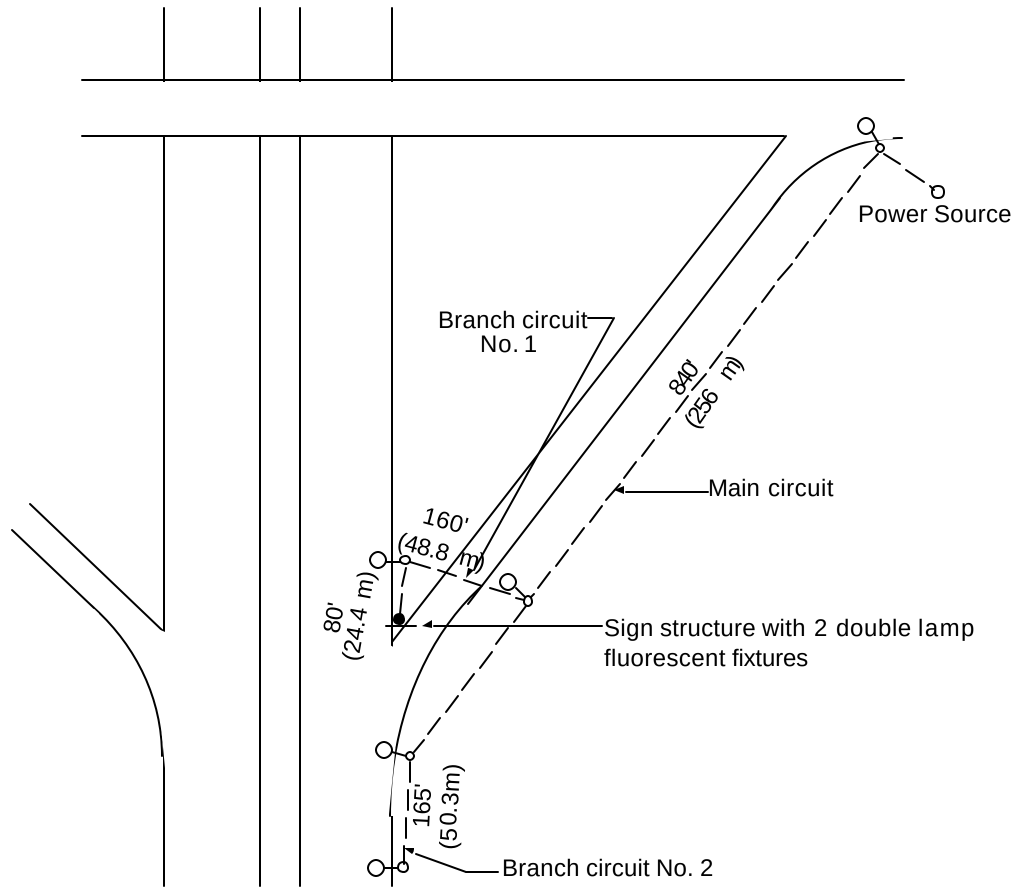

Figure 355.02.03 Multiple Lighting System Branch Conduits

Main Circuit:

Section	Accumulative Length	Length & Amperes				
1	100' (30.5 m)	100	x	2.1	=	210
2	100' (30.5 m)	940	x	12.5	=	11,750
	840' (256 m)					
		L	x	I	=	11,960

$\frac{24 \times 11{,}960}{7.2}$ = 39,866 Circular Mils = #4 AWG wire (minimum size used)

Use #4 AWG wire for the main circuit and #6 AWG wire for the branch circuits.

355.03 Structure Illumination. A number of items must be included in roadway structures to accommodate the light units and electrical circuits being installed or planned in the future. They normally consist of the following items:

- Light Unit Mounting Pedestal is an integral part of the structure and normally provides an 11-inch anchor bolt circle for a 40 foot (12.19 m) luminaire support pole. When 50-foot (15.24 m) mounting heights are used, it requires a 14.5 inch (368 mm) bolt circle and should be specified by a special note on the plan sheets.

- Plastic and Rigid Steel Conduit is installed in the structure and through the headwall for existing or future electrical circuits.

- Inserts installed on structure for attachment of conduit, circuit breaker panels, and light fixtures.

- Junction boxes and circuit breaker panels mounted on the structure for electrical circuits or as a conduit cover on light unit pedestals.

- Conduit expansion fittings installed at each expansion joint in the structure.

The structure electrical requirements must be determined and integrated with the structure design so that all necessary electrical facilities will be provided. The Headquarters Traffic Section will coordinate these requirements with the Bridge Engineer after receiving the necessary data from the District Traffic Engineer.

It must be noted that these requirements apply to grade separations, canal or stream bridges, and railroad structures as well as interchange structures where electrical facilities are involved.

355.04 Overhead Sign Illumination. Overhead signs mounted on sign structures shall be illuminated with high-pressure sodium units. The lighting units shall be mounted in front of the bottom edge of the sign and so aimed that from the driver's position the sign surface appears to be uniformly illuminated. See Figure 151.05.05-01 for typical installation requirements and details.

355.05 Special Lighting Considerations. There are a number of special items that must be considered to provide the maximum light intensity at the desirable locations on the roadway without creating a conflict with other roadway features or unnecessary glare to the road user.

355.05.01 Light Unit Location in Relation to Raised Channelization Nose. It is desirable to provide a high level of light intensity on the nose of raised channelization when the introduction of raised channelization is being illuminated for the motorist. Normally, the light intensity on raised nosing shall not be less than 1.0 average maintained foot-candles.

355.05.02 Left Turn Bays. Where lighting is provided for roadway channelization, it is desirable to provide a light unit at or near the entrance to left turn bays. Location of a light at this point will provide a higher illumination level and help show the area where the motorists must maneuver into this special turn lane.

355.05.03 Location of Light Units Adjacent to Overhead Roadway Structures. Occasionally, it is necessary to locate light units adjacent to roadway structures whereby the motorist on the overhead roadway structure is at or near the elevation of the luminaire unit. This creates a glare problem for the vehicle driver looking horizontally into the luminaire unit, particularly when approaching from the front of the luminaire. To decrease the problem, light units should be located at least 50 feet (15.24 m) away from the adjacent roadway overpass structures with glare shields installed on the luminaires or cutoff type luminaires installed.

355.05.04 Light Unit Spacing in Relation to Overhead Sign Structures. Overhead sign structures are provided with separate lighting units. Street lighting units immediately adjacent to the sign face interfere with the light distribution of the overhead sign lighting units. Accordingly, street lighting units should be located directly over the sign structure or placed as far as possible from the sign structure to reduce light cutoff by sign panels or light interference on the sign faces.

355.06 Support Pole And Conductor Clearance. Vertical and horizontal clearances for poles and overhead conductors are necessary for the safety of the general public, workmen, vehicle clearance, and persons working on top of railroad cars. Therefore, the following clearances shall be maintained:

- Where railroad tracks are paralleled or crossed by overhead lines, the poles shall, if practicable, be located no less than 12 feet (3.66 m) from the nearest track rail.

- Vertical clearance over railroad tracks handling freight cars on top of which men are permitted shall be 27 feet (8.23 m) for conductors carrying 750 volts or less and 28 feet (8.53 m) for conductors carrying 750 to 15,000 volts.

- Conductors crossing over public streets, alleys or roads in urban or rural districts shall have a clearance of 18 feet (5.49 m) (750 volts or less) or 20 feet (6.1 m) (750 to 15,000 volts).

- Supply wiring emerging from underground risers shall have a minimum vertical clearance of 14 feet (4.27 m) (750 volts or less) when on the side of the pole adjacent to vehicular traffic and 8 feet (2.44 m) (750 volts or less) when on the opposite side of the pole or 16 feet (4.88 m) and 11 feet (3.35 m), respectively, for 750 to 15,000 volts.

- Poles for electrical service or support of luminaires shall be located at least 4 feet (1.22 m) from any adjacent facilities that might interfere with electrical maintenance requirements on the pole or adjacent to the pole on the ground.

- Electrical circuits for lighting shall have a minimum clearance from other electrical conductors, communication cables, buildings, and other miscellaneous structure that are primarily dependent on circuit voltages.

Lighting electrical circuits that are closer than 4 feet (1.22 m) either horizontally or vertically from the above items shall be brought to the attention of the Headquarters Traffic Section for determination of proper safety clearance.

Vertical clearances must be determined by using the final unloaded sag in the wire and increased sag due to an increase in span length.

355.07 Pole Locations And Foundation Elevations. The breakaway features of lighting poles are designed to have a final graded ground elevation for the breakaway features to function properly when hit by a vehicle. Additionally, the foundation and anchor bolts must not protrude more than 4 inches (102 mm) above the ground so that they do not snag the under carriage of a vehicle. Therefore, it is necessary that the pole foundation elevations be closely coordinated with the slope grading and final finished elevations. The contractor shall be provided finished elevations for the top of all pole foundations. Although the lighting is designed for a specific mounting height above the roadway, this distance can vary a few feet (meters) without significantly changing the lighting design. The control parameter is to match the foundation elevation with the finished surrounding ground elevation.